Claims

[c1] 1.A light-emitting device comprising a light-emitting member that comprises a first electrode, a second electrode, and at least one organic electroluminescent ("EL") material disposed between said first and second electrodes, said light-emitting member being disposed on a substrate and emitting first electromagnetic ("EM") radiation having a first spectrum when an electrical voltage is applied across said electrodes; and at least one organic photoluminescent ("PL") material disposed in a path of light emitted by said light-emitting member, said organic PL material absorbing a portion of said first EM radiation and emitting second EM radiation having a second spectrum.

[c2] 2.The light-emitting device according to claim 1 further comprising at least one inorganic PL material disposed adjacent to at least one of said organic EL material and said organic PL material, said inorganic PL material absorbing a portion of said first radiation and emitting third radiation having a third spectrum.

[c3] 3.The light-emitting device according to claim 2, wherein light emitted from said light-emitting device has a correlated color temperature in a range from about 3000 K to about 6500 K.

[c4] 4.The light-emitting device according to claim 1 further comprising a light-scattering material disposed in a path of light emitted from said light-emitting member.

[c5] 5.The light-emitting device according to claim 1, wherein said organic PL material is dispersed in a layer of a polymeric material, said layer being disposed on said light-emitting member.

[c6] 6.The light-emitting device according to claim 2, wherein said organic PL material and said inorganic PL material are dispersed in separate layers of polymeric materials, said layers being disposed on said light-emitting member.

[c7] 7.The light-emitting device according to claim 4, wherein said scattering material is in a form of particles having a size in a range from about 10 nm to about 100 micrometers that are dispersed in a film of a polymeric material.

[c8] 8.The light-emitting device according to claim 7, wherein said film containing dispersed particles of light-scattering material is disposed adjacent to said inorganic PL material.

[c9] 9.The light-emitting device according to claim 1, wherein said first spectrum has wavelengths in a range from near ultraviolet ("UV") to red.

[c10] 10.The light-emitting device according to claim 9, wherein said wavelengths are in a range from about 300 nm to about 770 nm.

[c11] 11.The light-emitting device according to claim 10, wherein said wavelengths are preferably in a range from about 300 nm to about 550 nm.

[c12] 12.The light-emitting device according to claim 1, wherein said second spectrum has wavelengths in a range from about 500 to about 770 nm.

[c13] 13.The light-emitting device according to claim 12, wherein said wavelengths are preferably in a range from about 550nm to about 770 nm.

[c14] 14.The light-emitting device according to claim 2, wherein said third spectrum has wavelengths in a range from about 500 nm to about 770 nm.

[c15] 15.The light-emitting device according to claim 6, wherein said substrate and said polymeric materials have refractive indices from about 1.4 to about 1.6.

[c16] 16.The light-emitting device according to claim 1, wherein said first electrode comprises a material selected from the group consisting of K, Li, Na, Mg, La, Ce, Ca, Sr, Ba, Al, Ag, In, Sn, Zn, Zr, Sm, Eu, alloys thereof, and mixtures thereof.

[c17] 17.The light-emitting device according to claim 1, wherein said at least one organic EL material is selected from the group consisting of poly(n-vinylcarbazole), poly(alkylfluorene), poly(paraphenylene), polysilanes, derivatives thereof, mixtures thereof, and copolymers thereof.

[c18] 18.The light-emitting device according to claim 1, wherein said at least one organic EL material is selected from the group consisting of 1,3,5-tris{n-(4-diphenylaminophenyl) phenylamino} benzene, phenylanthracene, tetraarylethene, coumarin, rubrene, tetraphenylbutadiene, anthracene,

perylene}, coronene, aluminum-(picolymethylketone)-bis{2,6-di(t-butyl) phenoxide}, scandium-(4-methoxy-picolymethylketone)-bis(acetylacetonate), aluminum-acetylacetonate, gallium-acetylacetonate, and indium-acetylacetonate.

[c19] 19.The light-emitting device according to claim 18, wherein said at least one organic EL material is carried in a substantially transparent polymer.

[c20] 20.The light-emitting device according to claim 1, wherein said second electrode comprises a materials elected from the group consisting of ITO, tin oxide, indium oxide, zinc oxide, indium zinc oxide, and mixtures thereof.

[c21] 21.The light-emitting device according to claim 1, wherein said organic PL material is at least one material selected from the group consisting of perylenes, benzopyrenes, coumarin dyes, polymethine dyes, xanthene dyes, oxobenzanthracene dyes, perylenebis(dicarboximide), pyrans, thiopyrans, and azo dyes.

[c22] 22.The light-emitting device according to claim 1, wherein said inorganic PL material is at least one material selected from the group consisting of $(Y_{1-x}Ce_x)_3Al_5O_{12}$; $(Y_{1-x-y}Gd_xCe_y)_3Al_5O_{12}$; $(Y_{1-x}Ce_x)_3(Al_{1-y}Ga_y)O_{12}$; $(Y_{1-x-y}Gd_xCe_y)(Al_{5-z}Ga_z)O_{12}$; $(Gd_{1-x}Ce_x)Sc_2Al_3O_{12}$; $Ca_8Mg(SiO_4)_4Cl_2:Eu^{2+},Mn^{2+}$; $GdBO_3:Ce^{3+},Tb^{3+}$; $CeMgAl_{11}O_{19}:Tb^{3+}$; $Y_2SiO_5:Ce^{3+},Tb^{3+}$; $BaMg_2Al_{16}O_{27}:Eu^{2+},Mn^{2+}$; $Y_2O_3:Bi^{3+},Eu^{3+}$; $Sr_2P_2O_7:Eu^{2+},Mn^{2+}$; $SrMgP_2O_7:Eu^{2+},Mn^{2+}$; $(Y,Gd)(V,B)O_4:Eu^{3+}$; $3.5MgO{\cdot}0.5MgF_2{\cdot}GeO_2:Mn^{4+}$ (magnesium fluorogerminate); $BaMg_2Al_{16}O_{27}:Eu^{2+}$; $Sr_5(PO_4)_{10}Cl_2:Eu^{2+}$; $(Ca,Ba,Sr)(Al,Ga)_2S_4:Eu^{2+}$; $(Ba,Ca,Sr)_5(PO_4)_{10}(Cl,F)_2:Eu^{2+},Mn^{2+}$; $Lu_3Al_5O_{12}:Ce^{3+}$; $Tb_3Al_5O_{12}:Ce^{3+}$; and mixtures thereof; wherein $0 \leq x \leq 1$, $0 \leq y \leq 1$, $0 \leq z \leq 5$ and $x+y \leq 1$.

[c23] 23.The light-emitting device according to claim 7, wherein said light-scattering material is selected from the group consisting of rutile (TiO_2), hafnia (HfO_2), zirconia(ZrO_2), zircon ($ZrO_2 \cdot SiO_2$), gadolinium gallium garnet ($Gd_3Ga_5O_{12}$), barium sulfate, yttria (Y_2O_3), yttrium aluminum garnet ("YAG", Y_3Al_5

O_{12}), calcite ($CaCO_3$), sapphire (Al_2O_3), diamond, magnesium oxide, germanium oxide, and mixtures thereof.

[c24] 24.A light-emitting device comprising:
(1)light-emitting member that comprises a first electrode and a second electrode and at least one organic EL material disposed between said first and second electrodes, said light-emitting member being disposed on a substrate and emitting first EM radiation having a first spectrum when an electrical voltage is applied across said electrodes, said first spectrum having wavelengths in a range from about 300 nm to about 770 nm;
(2)at least one layer of at least one organic PL material disposed adjacent to said light-emitting member, said organic PL material absorbing a first portion of said first EM radiation and emitting second EM radiation having a second spectrum having wavelengths in a range from about 500 nm to about 770 nm;
(3)at least one layer of at least one inorganic PL material disposed adjacent to at least one of said organic EL material and said organic PL material, said inorganic PL material absorbing a second portion of said first EM radiation and emitting third EM radiation having a third spectrum having wavelengths in a range from about 500 nm to about 700 nm; and
(4)a layer comprising at least one light-scattering material disposed in a path of light emitted from said light-emitting member;
wherein light emitted from said light-emitting device has a correlated color temperature in a range from about 3000 K to about 6500 K.

[c25] 25.The light-emitting device of claim 24, wherein each of said organic EL material, said at least one organic PL material, and said at least one inorganic PL material covers more than about 10 percent of a surface of said substrate and exhibits continuity to a naked eye.

[c26] 26.The light-emitting device of claim 24, wherein each of said organic EL material, said at least one organic PL material, and said at least one inorganic PL material covers substantially an entire surface of said substrate and exhibits continuity to a naked eye.

[c27] 27.A light-emitting device comprising:

(1)a light-emitting member that comprises a first electrode and a second electrode and at least one organic EL material disposed between said first and second electrodes, said light-emitting member being disposed on a substrate and emitting first EM radiation having a first spectrum when an electrical voltage is applied across said electrodes;
(2)at least one layer of at least one organic PL material disposed adjacent to said light-emitting member, said organic PL material absorbing a first portion of said first EM radiation and emitting second EM radiation having a second spectrum;
(3)at least one layer containing an additional material selected from the group consisting of:
(a)at least one inorganic PL material disposed adjacent to at least one of said organic EL material and said organic PL material, said inorganic PL material absorbing a second portion of said first EM radiation and emitting third EM radiation having a third spectrum; and
(b)at least one light-scattering material disposed in a path of light emitted from said light-emitting member; and
(4)a substantially transparent encapsulant layer disposed around an assembly of (1), (2) and (3).

[c28] 28.The light-emitting device according to claim 27, wherein said encapsulant is selected from the group consisting of silicone, epoxy, and silicone-functionalized epoxy.

[c29] 29.A light-emitting device comprising:
(1)a light-emitting member that comprises a first electrode and a second electrode and at least one organic EL material disposed between said first and second electrodes, said light-emitting member being disposed on a substrate and emitting first EM radiation having a first spectrum when an electrical voltage is applied across said electrodes, said first spectrum having wavelengths in a range from about 300 nm to about 770 nm;
(2)at least one layer of at least one organic PL material disposed adjacent to said light-emitting member, said organic PL material absorbing a first portion of said first EM radiation and emitting second EM radiation having a second

spectrum having wavelengths in a range from about 500 nm to about 770 nm;
(3)at least one layer of at least one inorganic PL material disposed adjacent to at least one of said organic EL material and said organic PL material, said inorganic PL material absorbing a second portion of said first EM radiation and emitting third EM radiation having a third spectrum having wavelengths in a range from about 500 nm to about 770 nm; and
(4)a layer containing at least one light-scattering material disposed in a path of light emitted from said light-emitting member;
wherein light emitted from said light-emitting device has a correlated color temperature in a range from about 3000 K to about 6500 K; each of said organic EL material, said at least one organic PL material, and said at least one inorganic PL material covers more than about 10 percent of a surface of said substrate and exhibits continuity to a naked eye; said first electrode comprises a material selected from the group consisting of K, Li, Na, Mg, La, Ce, Ca, Sr, Ba, Al, Ag, In, Sn, Zn, Zr, Sm, Eu, alloys thereof, and mixtures thereof; said at least one organic EL material is selected from the group consisting of poly(n-vinylcarbazole), poly(alkylfluorene), poly(paraphenylene), polysilanes, derivatives thereof, mixtures thereof, copolymers thereof, 1,3,5-tris{n-(4-diphenylaminophenyl) phenylamino} benzene, phenylanthracene, tetraarylethene, coumarin, rubrene, tetraphenylbutadiene, anthracene, perylene, coronene, aluminum-(picolymethylketone)-bis{2,6-di(t-butyl)phenoxide}, scandium-(4-methoxy-picolymethylketone)-bis(acetylacetonate), aluminum-acetylacetonate, gallium-acetylacetonate, and indium-acetylacetonate; said second electrode comprises a material elected from the group consisting of ITO, tin oxide, indium oxide, zinc oxide, indium zinc oxide, and mixtures thereof; said organic PL material is at least one material selected from the group consisting of perylenes, benzopyrenes, coumarin dyes, polymethine dyes, xanthene dyes, oxobenzanthracene dyes, perylenebis(dicarboximide), pyrans, thiopyrans, and azo dyes; said inorganic PL material is at least one material selected from the group consisting of $(Y_{1-x}Ce_x)_3Al_5O_{12}$; $(Y_{1-x-y}Gd_xCe_y)_3Al_5O_{12}$; $(Y_{1-x}Ce_x)_3(Al_{1-y}Ga_y)O_{12}$; $(Y_{1-x-y}Gd_xCe_y)(Al_{5-z}Ga_z)O_{12}$; $(Gd_{1-x}Ce_x)Sc_2Al_3O_{12}$; $Ca_8Mg(SiO_4)_4Cl_2$:Eu^{2+},Mn^{2+}; $GdBO_3$:Ce^{3+}, Tb^{3+}; $CeMgAl_{11}O_{19}$:Tb^{3+}; Y_2SiO_5:Ce

$^{3+}$,Tb^{3+}; $BaMg_2Al_{16}O_{27}:Eu^{2+},Mn^{2+}$; $Y_2O_3:Bi^{3+},Eu^{3+}$; $Sr_2P_2O_7:Eu^{2+},Mn^{2+}$; $SrMgP_2O_7:Eu^{2+},Mn^{2+}$; $(Y,Gd)(V,B)O_4:Eu^{3+}$; $3.5MgO.0.5MgF_2.GeO_2:Mn^{4+}$ (magnesium fluorogerminate); $BaMg_2Al_{16}O_{27}:Eu^{2+}$; $Sr_5(PO_4)_{10}Cl_2:Eu^{2+}$; $BaMg_2Al_{16}O_{27}:Eu^{2+}$; $Sr_5(PO_4)_{10}Cl_2:Eu^{2+}$; $(Ca,Ba,Sr)(Al,Ga)_2S_4:Eu^{2+}$; $(Ba,Ca,Sr)_5(PO_4)_{10}(Cl,F)_2:Eu^{2+},Mn^{2+}$; $Lu_3Al_5O_{12}:Ce^{3+}$; $Tb_3Al_5O_{12}:Ce^{3+}$; and mixtures thereof; wherein $0 \leq x \leq 1$, $0 \leq y \leq$, $0 \leq z \leq 5$ and $x+y \leq 1$; and said light-scattering material is selected from the group consisting of rutile (TiO_2), hafnia (HfO_2), zirconia(ZrO_2), zircon ($ZrO_2 \bullet SiO_2$), gadolinium gallium garnet ($Gd_3Ga_5O_{12}$), barium sulfate, yttria (Y_2O_3), yttrium aluminum garnet ("YAG", $Y_3Al_5O_{12}$), calcite ($CaCO_3$), sapphire (Al_2O_3), diamond, magnesium oxide, germanium oxide.

[c30] 30.A method of making a light-emitting device that is based on at least one organic EL material, said method comprising the steps of:

(1)providing a substrate;

(2)forming a light-emitting member in a process comprising the steps of:

(a)depositing a first electrically conducting material on one surface of said substrate to form a first electrode;

(b)depositing said at least one organic EL material on said first electrode; and

(c)depositing a second electrically conducting material on said organic EL material to form a second electrode; and

(3)disposing at least one organic PL material adjacent to said light-emitting member.

[c31] 31.The method according to claim 30 further comprising the step of disposing at least one inorganic PL material adjacent to said organic PL material.

[c32] 32.The method according to claim 30 further comprising the step of disposing at least one light-scattering material in a path of light emitted from at least one of said light-emitting member and said organic PL material.

[c33] 33.The method according to claim 31 further comprising the step of disposing at least one light-scattering material in a path of light emitted from at least one of said light-emitting member, said organic PL material, and said inorganic PL

material.

[c34] 34.The method according to claim 30, wherein said steps of depositing said first and second electrically conducting materials are selected from the group consisting of physical vapor deposition, chemical vapor deposition, and sputtering.

[c35] 35.The method according to claim 30, wherein said step of depositing said at least one organic EL material is selected from the group consisting of physical vapor deposition, chemical vapor deposition, spin coating, dip coating, spraying, ink-jet printing, and casting.

[c36] 36.The method according to claim 30, wherein said step of disposing at least one organic PL material comprises depositing said organic PL material by a method selected from the group consisting of physical vapor deposition, chemical vapor deposition, spin coating, dip coating, spraying, ink-jet printing, and casting.

[c37] 37.The method according to claim 30, wherein said step of disposing at least one organic PL material comprises dispersing said organic PL material in a substantially transparent polymeric material to form a mixture, casting said mixture into a film by a doctor blade method, curing said film, and disposing said film adjacent to said light-emitting member.

[c38] 38.The method according to claim 31, wherein said step of disposing at least one inorganic PL material comprises dispersing said inorganic PL material in a substantially transparent polymeric material to form a mixture and depositing said mixture on said organic PL material by a method selected from the group consisting of spin coating, dip coating, spraying, ink-jet printing, and casting.

[c39] 39.The method according to claim 31, wherein said step of disposing at least one inorganic PL material comprises dispersing said inorganic PL material in a substantially transparent polymeric material to form a mixture and casting said mixture into a film using a doctor blade method, curing said film, and disposing said film adjacent to said organic PL material.

[c40] 40.The method according to claim 32, wherein said step of disposing at least one light-scattering material comprises dispersing particles of said light-scattering material in a substantially transparent polymeric material to produce a mixture, forming a film of said mixture, and disposing said film adjacent to at least one of said organic EL material and said organic PL material.

[c41] 41.The method according to claim 33, wherein said step of disposing at least one light-scattering material comprises dispersing particles of said light-scattering material in a substantially transparent polymeric material to produce a mixture, forming a film of said mixture, and disposing said film adjacent to at least one of said organic EL material, said organic PL material, and said inorganic PL material.

[c42] 42.The method according claim 30, wherein said step of forming said light-emitting member further comprises depositing at least one additional layer of an organic material between one of said electrodes and said organic EL material for a function selected from the group consisting of hole injection enhancement, hole transport, and electron injection enhancement and transport.

[c43] 43.A method of making a light-emitting device that is based on at least one organic EL material, said method comprising the steps of:
(1)providing a substrate on which a light-emitting member has been formed, said light-emitting member comprising a first electrode, a second electrode, and said at least one organic EL material;
(2)providing at least one film comprising at least one organic PL material dispersed in a substantially transparent polymeric material; and
(3)laminating said substrate having said light-emitting member together with said at least one film.

[c44] 44.The method of making a light-emitting device according claim 43, wherein said step of providing at least one film comprises providing at least one film comprising at least one organic PL material and at least one film comprising at least one inorganic PL material.

[c45] 45.The method of making a light-emitting device according claim 43, wherein said step of providing at least one film comprises providing at least one film comprising at least one organic PL material, at least one film comprising at least one inorganic PL material, and at least one film comprising a light-scattering material.

[c46] 46.A light-emitting display comprising a plurality of light-emitting devices according to claim 1 mounted on a support.

[c47] 47.The light-emitting display according to claim 46, wherein each of said light-emitting devices comprises a continuous layer of organic EL material.

[c48] 48.A light-emitting display comprising a plurality of light-emitting devices according to claim 27 mounted on a support.

[c49] 49.A light-emitting display comprising a plurality of light-emitting devices according to claim 29 mounted on a support.